THE EFFECTS OF THE STIMULUS-REINFORCER CORRELATION IN A DISCRETE-TRIALS IRT>t PROCEDURE[1]

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The correlation between a keylight and food in a discrete-trials, interresponse-time-greater-than 6-sec (IRT>6-sec) procedure was varied by manipulating the rate of response-independent food presentation in the intertrial interval. When the correlation was positive, the rates of pecking in the IRT>6-sec condition were high and food was obtained on only about 5% of the trials. Likewise, responding was maintained at a high rate in yoked birds that received the same presentations of the light and food as the birds in the IRT>6-sec condition. When the rate of reinforcement between trials was equated to or made greater than the rate of reinforcement within trials, the response rate decreased for all birds, and those decreases were considerably larger for the yoked birds. However, the percentage of trials in which reinforced responses occurred under the IRT>6-sec procedure did not increase substantially when the light and food were either uncorrelated or negatively correlated. The percentage of trials in which a reinforcer was obtained increased when the keylight was left on continuously and the discriminative stimulus was not presented on the key. The results show that the stimulus-reinforcer correlation affects responding in the discrete-trials IRT>6-sec procedure, but that the effects of the stimulus-reinforcer correlation vary as a function of whether reinforcement is response-dependent or response-independent. The differences between the effects of response-independent and response-dependent pairings and nonpairings of the light and food are best accounted for in terms of differences in the control of responding by background stimuli.

Key words: autoshaping, stimulus-reinforcer effects, IRT>t, discrete-trials, background stimuli, key peck, pigeons

In pigeons, repeated forward pairings in time of a brief, localized keylight with food presentation lead to the acquisition and maintenance of approaches toward and pecks at the key (Brown & Jenkins, 1968; Hearst & Franklin, 1977; Wasserman, Franklin, & Hearst, 1974). Most of the research on autoshaping (for reviews, see Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977) has established that autoshaped responses are controlled primarily by stimulus-reinforcer variables such as the temporal relationship between the illumination of the key and the presentation of food. Inasmuch as the stimulus-reinforcer pairings and nonpairings that influence autoshaping are also present in many of the procedures used to study operant conditioning (Jenkins, 1973; Kimble, 1961; Skinner, 1938; Terrace, 1973), much of the responding that appears to be controlled by contingencies of reinforcement may actually be controlled by stimulus-reinforcer variables (Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977). It is important to assess empirically the contribution of stimulus-reinforcer variables in operant conditioning procedures both to identify the antecedents of responding and to evaluate the status of the distinction between classical and instrumental conditioning (Hearst, 1975).

Presently, we have only a rudimentary understanding of the effects of stimulus-reinforcer variables in operant conditioning procedures. Numerous studies have established that stimulus-reinforcer variables influence responding in the procedures used to analyze the phenomena of stimulus control, particularly behavior contrast (Hearst & Jenkins, 1974; Keller, 1974; Redford & Perkins, 1974; Schwartz & Gamzu, 1977; Spealman, 1976). In those studies, reinforcers were typically presented according to variable-interval schedules, which characteristically maintain moderate to high rates of responding (Zeiler, 1977). It is possible that the effects of stimulus-reinforcer variables in operant conditioning pro-

cedures depend on the schedule of reinforcement that is in effect. By studying the effects of stimulus-reinforcer variables in a variety of procedures involving various schedules of reinforcement, one may not only ascertain the generality of the effects of stimulus-reinforcer variables but also acquire insight into the processes whereby those variables influence responding in operant conditioning procedures.

The main purpose of this experiment was to assess the effects of the stimulus-reinforcer correlation on pecking that was reinforced according to an interresponse-time-greater-than-6-sec (IRT>6-sec) schedule in a discrete-trials procedure. For several reasons, that procedure seems particularly worthy of investigation. First, since that procedure involves the use of discrete trials, the temporal parameters that give rise to autoshaping (e.g., the duration of trials and intertrial intervals; cf. Perkins, Beavers, Hancock, Hemmendinger, & Ricci, 1975; Terrace, Gibbon, Farrell, & Baldock, 1975) may be built into the operant conditioning procedure. By taking that approach, one may assess the role of stimulus-reinforcer variables in an operant conditioning procedure under conditions that are known to produce strong effects in the autoshaping procedure. Second, in the discrete-trials-IRT>6-sec procedure, the effects of stimulus-reinforcer and response-reinforcer variables appear to be pitted against each other (Schwartz & Williams, 1971). If the discriminative stimulus in that procedure were a localized keylight, then the response-dependent pairings of the light and food would presumably lead to increases in the rate of pecking. On the other hand, the dependency between long interresponse times and food should lead to decreases in the rate of pecking (Zeiler, 1977). Since the two factors are pitted against each other (as they are in the discrete-trials omission procedure; cf. Schwartz & Williams, 1972; Williams & Williams, 1969), one may use the discrete-trials IRT>6-sec procedure to evaluate the relative contributions of stimulus-reinforcer and response-reinforcer pairings to responding.

The foregoing approach would be misdirected if performance in the discrete-trials IRT>6-sec procedure were known to be well controlled by the schedule of reinforcement. In fact, however, Schwartz & Williams (1971) studied performance in a discrete-trials procedure that involved IRT>6-sec schedule of

reinforcement, and they reported that their pigeons pecked at such a high rate that reinforcers were not obtained in more than 90% of the trials, even after 45 sessions of training. (Under other conditions or after extended training, responding may be well controlled by an IRT>6-sec schedule; cf. Catania, 1970; Richardson & Clark, 1976; Zimmerman, 1961). Perhaps the elicitation of pecking by the light outweighed the effects of the reinforcement contingency. More specifically, the light was paired with food on trials in which a reinforced response occurred, and the effects of those light-food pairings could have offset the effects of the response-reinforcer pairings (Schwartz & Williams, 1971).

In the experiment reported here, the effects of the stimulus-reinforcer relation on pecking in the discrete-trials IRT>6-sec procedure was assessed by varying the rate of food presentation between trials in the absence of the keylight. Previous studies of autoshaping (Gamzu & Williams, 1971, 1973; Wasserman et al., 1974) have shown that pecking is acquired and maintained when the rate of reinforcement in the presence of the light exceeds the rate of reinforcement in the absence of the light. Under those conditions, a positive correlation is said to exist between the light and the food. In contrast, pecking is neither acquired nor maintained when the rate of reinforcement in the presence of the light is equal to or less than the rate of reinforcement in the absence of the light (Gamzu & Williams, 1971, 1973; Wasserman et al., 1974), that is, when the light and food are either uncorrelated or negatively correlated. If the light-food correlation contributes to responding, then performance in the IRT>6-sec procedure should vary as a function of the correlation between the light and food.

A second purpose of this experiment was to compare the effects of the light-food correlation on pecking in two situations: one in which the light-food pairings were dependent on pecking (the IRT>6-sec procedure), and one in which the light-food pairings were independent of pecking. Accordingly, each bird used in the IRT>6-sec condition was assigned a yoked partner that was given the light and the food whenever the bird in the IRT>6-sec condition received them, but for the yoked birds, the light and the food were always presented independently of responding. By com-

paring the effects of response-dependent pairings with those of response-independent pairings, one may help to test an important theoretical assumption that has not yet been fully tested—that the response-dependent pairings and nonpairings of the light and food have effects that are similar to those of response-independent pairings. That assumption has been supported in some previous research (Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977), but it needs to be tested under a wider variety of conditions, for it is central to the view that the autoshaping phenomenon has important implications for the analysis of responding in operant conditioning procedures.

METHOD

Subjects

Eight White Carneaux pigeons approximately 1 to 2 yr old were maintained at 80% of their free-feeding weights. All of the birds were experimenally naive, and they were assigned to two groups of four on a random basis.

Apparatus

Two identical Grason-Stadler pigeon chambers (Model 1121) that were enclosed in sound-attenuated cubicles were used. The standard right key of each chamber had been replaced by a pecking key (BRS/LVE, Model 121-16) that had a Polacoat-projection surface designed to reduce reflections from the surrounding environment. The keys were operated by a minimum force of about .15 N. Those keys, the only ones used in this experiment, could be transilluminated with white light by 1.8-W lamps that were housed in an in-line display cell (Industrial Electronics Engineers).

Each chamber was illuminated at all times by a 7-W white lamp that was located in the center of the transparent ceiling. This houselight had a plastic housing that deflected the light fairly evenly throughout the entire chamber. White noise was (except as noted) constantly delivered through speakers mounted on the front walls of the chambers, and additional masking noise was provided by the sound of the ventilating fans. Each chamber contained a standard food tray that was filled with mixed grains. Experimental events were programmed and recorded by conventional relay equipment located in an adjacent room.

Procedure

Three sessions were devoted to magazine training. In the first two of those sessions, each bird was placed in the chamber for 20 min with the houselight on and with the daily ration of food continuously available in the food hopper. On the third session, food was presented independently of responding according to a variable time (VT) 15-sec schedule, and the duration of food presentation was gradually decreased from 15 sec to 4 sec, at which value it remained throughout the entire experiment. Throughout the magazine training sessions, the keylight was off.

Following magazine training, the birds were trained to peck the illuminated key. The birds in the IRT>6-sec condition were trained through a procedure that involved both autoshaping and response-dependent reinforcement. Following variable intervals (Fleshler & Hoffman, 1962) that averaged 30-sec in duration, the keylight was turned on and a trial was begun. If no peck at the key occurred, the light stayed on for 6 sec and was followed immediately by the presentation of food. If a peck occurred before 6 sec had passed, the light went off and food was immediately presented. Thus, each peck in the presence of the light was reinforced. Pecks that occurred in the intertrial interval were recorded but had no programmed consequences. That training procedure was in effect for 3 sessions of 40 trials each. The purpose of explicitly reinforcing pecking was to eliminate off-key pecking.

The birds that later served in the yoked condition were trained to peck at the key through an autoshaping procedure similar to that described above. The main difference was that for the yoked birds responding had no programmed consequences. In that training procedure, trials occurred following variable intervals that averaged 30 sec in duration. On each trial, the keylight remained on for 6 sec and was followed immediately by the presentation of food. As for the birds in the IRT>6-sec condition, there were 3 training sessions with 40 trials in each.

Following the three sessions in which pecking was conditioned, the experiment proper began. Throughout the experiment, the birds were studied in pairs, and for each bird in the IRT>6-sec condition there was a yoked

bird in a separate chamber. The light and the food were always presented to the yoked bird at exactly the same times they were presented to the experimental bird, but for the yoked birds the presentations of the light and food were independent of their behavior. Since the programmed events that occurred in the environment of the yoked bird were completely dependent on the events that occurred in the environment of the bird in the IRT>6-sec condition, the conditions of the experiment will be described solely in terms of the procedures arranged for the birds in the IRT>6-sec condition.

In Phase 1 and in all subsequent phases of the experiment, a discrete-trials procedure was used, and within each trial an IRT>6-sec schedule of reinforcement was in effect. In each session, 50 trials were presented according to a VT 30-sec schedule (Fleshler & Hoffman, 1962). A trial was begun when the keylight was turned on. If no peck occurred within the first 6 sec of the trial, the first peck turned off the light and was followed immediately by the presentation of food. However, if one or more pecks occurred before 6 sec had elapsed within the trial, no food was presented on that trial and the keylight went off at the end of 6 sec. Furthermore, if the keylight came on and no peck had occurred at the end of 15 sec, the keylight was turned off automatically (limited-hold 9-sec) and no food was presented. Thus, the keylight was always on for at least 6 sec and no more than 15 sec within trials, and the exact schedule of reinforcement was therefore IRT>6-sec LH 9-sec. The purpose of limiting the duration of trials to 15 sec was to avoid long light presentations that might reduce the eliciting effects of the light. During the intertrial intervals, the key remained darkened, food was never presented, and responses had no programmed effects. During Phase 1, then, food was never presented in the absence of the light but was paired with the light on trials in which a reinforced response occurred. Thus, assuming the occurrence of reinforced responses, there was a positive correlation between the light and food, and the strength of that correlation depended upon the effectiveness of the IRT >6-sec schedule. Phase 1 lasted for 15 sessions since in the pilot study the response rates on an IRT>6-sec schedule like that of the present experiment did not fluctuate by more than

20% from the mean response rates that occurred during Sessions 10 through 15.

Immediately following Phase 1, Phase 2 of the experiment began and continued for 25 sessions. The conditions were the same as in Phase 1 with the following exception. In Phase 2, food was presented between trials according to an adjusting VT schedule that was programmed to deliver food at a rate that equaled or slightly exceeded the rate of food presentation within trials. The VT schedule was arranged by yoking a timer set at 6 sec with a probability gate and by using the output pulse from the probability gate to operate the feeder. Note that in this procedure, 6 sec was the minimum delay between an intratrial response or reinforcer and an intertrial reinforcer. At the beginning of each session, the probability gate was set at a value of .10. At that setting, food was delivered between trials at a rate of about one per min, which was about equal to the obtained rate of reinforcement within trials during Phase 1. The programmed rate of food presentation between trials was never less than one per min and was adjusted according to the schedule shown in Table 1 by changing the setting of the probability gate. If four or fewer reinforcers were obtained within the trials of a session, the setting of the probability gate remained at .10 throughout the entire session since the intratrial rate of reinforcement could not reach the intertrial rate of reinforcement of one per min. However, if, say, five reinforcers were delivered within trials, the intratrial rate of reinforcement could have exceeded the intertrial rate of one per min. Accordingly, on the presentation of the fifth reinforcer within trials, the setting of the probability gate was immediately increased from .10 to .15. The setting remained at that level for the remainder of the session unless more reinforcers were obtained within trials, and so on. The programmed rate of food presentation between trials was always slightly higher than the obtained rate of food presentation within trials. That conservative procedure was designed to guard against the possibility that the bird would obtain food within the last, say, three trials so that the overall correlation between the light and food within that session could unintentionally end up positive. Since in Phase 2, the rates of food presentation within and between trials were about equal in

Table 1

Adjusting Schedule for Presenting Food between Trials

Number of intratrial reinforcers obtained	Setting of the probability gate
1- 4	.10
5- 8	.15
9-10	.20
11-12	.25
13-15	.30
16-17	.35
18-20	.40

each session, the light and the food were uncorrelated.

In Phase 3, a positive correlation between the light and food was again established for 15 sessions, and the procedure was identical in all respects to that of Phase 1. The purpose of Phase 3 was to determine whether the differences in responding between Phases 1 and 2 resulted from differences in the light-food correlation or from increased training on the IRT>6-sec schedule.

In Phase 4, which lasted 20 sessions, food was presented between trials by the same means as in Phase 2. Unlike Phase 2, food was programmed to occur between trials at a rate that was about twice as great as the rate of food presentation within trials. Food presentation was programmed to occur during the intertrial interval at an average rate that was never less than 2.0 per min, and that was adjusted on the basis of the actual rate of food presentation within trials. In Phase 4, the rate of food presentation between trials was relatively high, and if the sessions had continued for 50 trials, it would have been impossible to maintain the birds at 80% of their free-feeding weights. Accordingly, the sessions were ended when food had been delivered a total of 50 times, regardless of the number of trials there had been. (In an unpublished pilot study by the author, the number of trials per session in a procedure identical to that of Phases 1 and 3 had been varied from 15 to 50 and had been observed to have no effect upon responding.)

In Phase 5, a positive correlation between the light and food was again established for 10 sessions, and the procedure was identical to that of Phases 1 and 3. As in Phase 3, the Phase 5 procedure served as a control for the effects of extended exposure to the IRT>6-sec schedule.

In Phase 6, which lasted for 20 sessions, the S^D was no longer the keylight but rather the offset of the white noise that was otherwise presented continuously. The keylight remained on constantly during all sessions. The procedure was similar to the previously described positive correlation conditions (Phases 1, 3, and 5) except that during each trial, the white noise was turned off. As in all the other phases of the experiment, food was delivered within a trial if the latency to the first peck within the trial was equal to or greater than 6.0 sec.

The rationale for removing the S^D from the key during Phase 6 was as follows. In the preceding positive correlation, the keylight had been differentially paired with food and could therefore have come to elicit pecking at the key, just as in the autoshaping experiment. But if the conditions were altered so that the light were no longer the S^D that was paired with food, then the light would presumably not elicit pecking and pecking would then be controlled primarily by the response-reinforcer contingency (Keller, 1974; Schwartz, 1975; Spealman, 1976). The absence of the white noise was used as the S^D in Phase 6 because that stimulus was not localized. If the S^D had been localized (e.g., a second keylight), then pecking would probably have been directed at that stimulus as the result of the pairings of that stimulus with food (Schwartz & Williams, 1971). The pecking that was directed at that localized S^D could have served as effective collateral behavior, and that behavior affects performance on the IRT>6-sec schedule (Laties, Weiss, & Weiss, 1969; Mc-Millan, 1969; Schwartz & Williams, 1971). Thus, if the S^D had been localized, then the removal of the eliciting effects of the light could have been confounded with the establishment of pecking as a mediating response.

In Phase 7, which lasted for 10 sessions, the keylight was again used as the S^D, and the white noise was on continuously. The procedure was identical to that of Phases 1, 3, and 5 in which there was a positive correlation between the light and food.

RESULTS

Table 2 shows the mean rate of pecking in each of the last five sessions of Phase 1 for the four pairs of birds. Table 2 shows that the response rates varied considerably over sessions for some birds such as P69 but not for

Table 2

Mean response rate (responses/min) for the last five
sessions in Phase 1.

Subject	Condition	Session					Overall mean
		11	12	13	14	15	
P70	IRT>6-sec	87	87	82	90	100	89
P71	Yoke	65	105	65	90	109	87
P46	IRT>6-sec	60	49	35	43	40	46
P35	Yoke	112	76	80	67	83	84
P72	IRT>6-sec	56	64	46	70	67	61
P73	Yoke	126	120	83	123	97	110
P67	IRT>6-sec	47	53	57	59	51	53
P69	Yoke	32	78	32	59	85	45

others such as P67. In general, the response
rates of the birds in the yoked condition were
more variable than were the rates of the birds
in the IRT>6-sec condition. However, over
the last five sessions of Phase 1, the respond-
ing of all subjects neither increased nor de-
creased systematically.

The last column of Table 2 shows the over-
all mean response rate for each bird for the
last five sessions of Phase 1, and that rate
served as a baseline for evaluating the effects
of the various conditions on the rate of peck-
ing. In order to facilitate comparisons of the
effects of the various conditions on the re-
sponse rates of the birds in the IRT>6-sec
and the yoked conditions, normalized rates
were calculated. The normalized rate for a
particular bird in a particular session was
defined as the ratio of the mean response rate
for that session to the mean response rate for
the last five sessions of Phase 1. Thus, a nor-
malized rate of 1.0 indicated that there was
no difference between the rate in a particular
session and the mean rate over the last five
sessions of Phase 1. Moreover, normalized rates
greater than 1.0 indicated increases in the
rate of responding relative to the baseline
level, and normalized rates less than 1.0 indi-
cated decreases in the rate of responding rela-
tive to the baseline level.

Figure 1 shows the normalized response
rates for each bird over blocks of two sessions
(except as noted) in all seven phases of the
experiment. In Phase 2, in which the light and
food were uncorrelated, the response rates of
all birds decreased substantially relative to
the last five sessions of Phase 1. For the four
birds in the IRT>6-sec condition, the re-
sponse rates decreased about 70%, 25%, 60%,
and 42%, respectively. For all four yoked

birds, responding gradually decreased to levels
near zero.

When Phase 3 began and there was once
more a positive correlation between the light
and food, the rates of responding increased
and became more variable for all birds. Fig-
ure 1 shows that the response rate for all
birds increased at least temporarily to a level
equal to or in excess of the baseline level of
responding.

The negative light-food correlation that was
instituted in Phase 4 brought about large
decreases in the rate of response for all birds.
Figure 1 shows that the decreases in the re-
sponse rates of the birds in the IRT>6-sec
condition were slightly larger than the de-
creases that had occurred in the uncorrelated
condition. The responding of three of the
birds in the yoked condition ceased soon after
the establishment of the negative correlation,
and the responding of the fourth bird in that
condition decreased rapidly to a level near
zero.

In Phase 5, the light-food correlation was
again positive. As shown in Figure 1, the re-
sponse rates of the birds in the IRT>6-sec
condition increased to a level just below that
from Phase 1. The response rates of two of
the birds in the yoked condition were slightly
below their baseline rates. Of the other birds
in the yoked condition, one responded at a
rate above the baseline level, and the other
responded infrequently.

In Phase 6, in which the S^D was the absence
of white noise, the response rates of all of the
birds in the IRT>6-sec condition decreased
gradually to very low levels. Figure 1 shows
that the decreases in rate for two of those birds
were considerably larger than those that had
occurred in any other phase of the experiment.
For the other two birds in the IRT>6-sec
condition, the decreases in response rate were
comparable in magnitude to those that had
occurred in the negative correlation condi-
tion. Large decreases in response rate also oc-
curred in two of the three yoked birds that had
continued to respond at substantial rates dur-
ing Phase 5. One yoked bird, however, pecked
at a high rate throughout Phase 6.

The decreases in response rate that occurred
during Phase 6 did not result from a failure of
the S^D to control responding. Table 3 shows
for each subject what proportion of the total
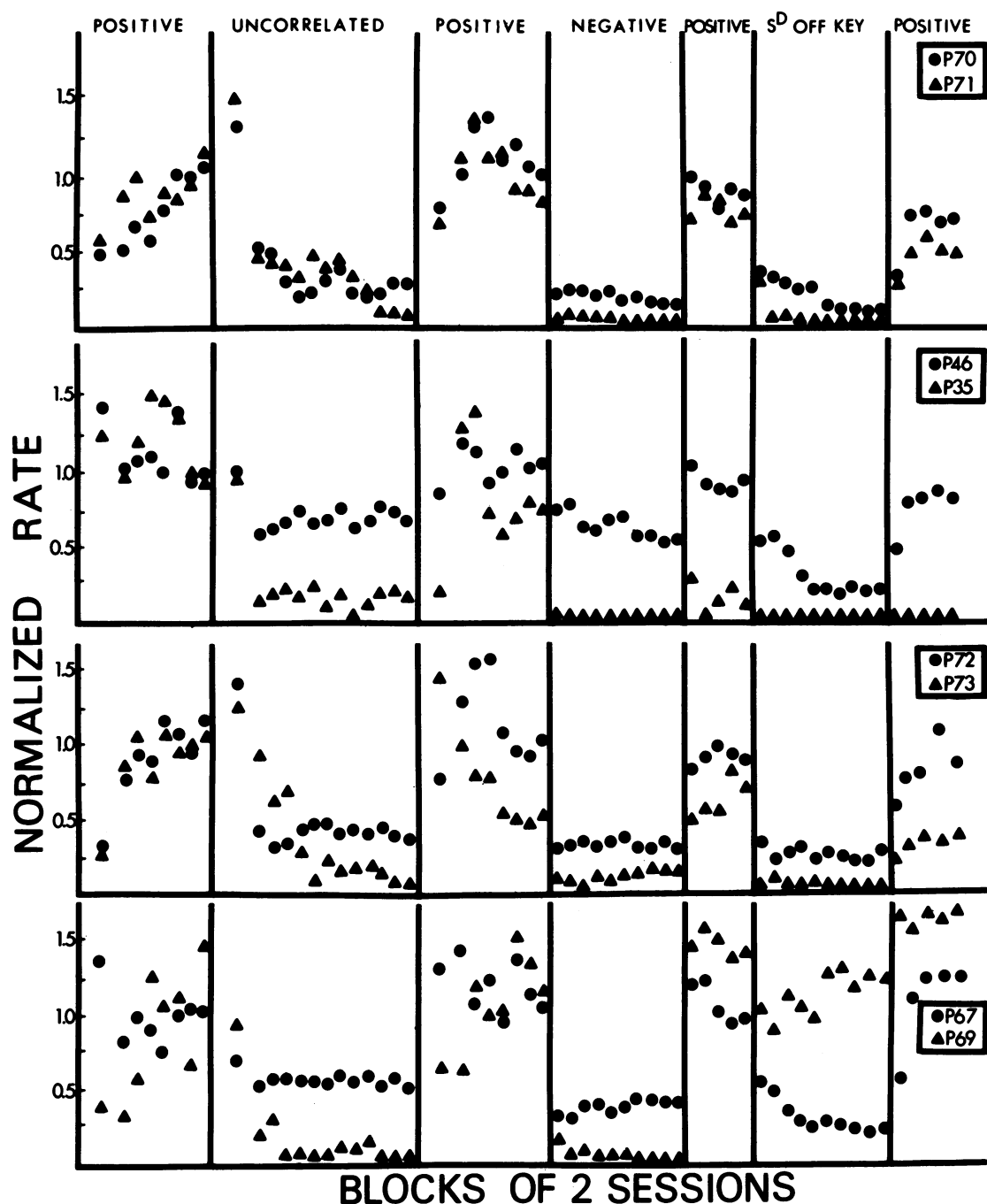number of pecks occurred in the presence of

Fig. 1. Normalized rates for each bird for blocks of two sessions. Each graph shows data for one bird in the IRT>6-sec condition (closed circles) and its yoked partner (triangles). The first data point in each of the first three phases show the normalized rates for one session.

the S^D during the last five sessions of Phase 6. Table 3 shows that the pecking that occurred was clearly controlled by the S^D.

In Phase 7, as in all of the positive correlation conditions, the response rates of most birds increased markedly relative to the preceding phase. However, the response rates of 8 of the 10 birds were below the rates that had occurred in Phase 1 in the initial positive correlation condition.

Table 3

Discrimination Indices [S^D responses/(S^D responses & S$^\Delta$ responses)] from Phase 6.

Subject	Condition	Index
P72	IRT>6-sec	.86
P73	Yoke	.95
P70	IRT>6-sec	.97
P71	Yoke	0
P46	IRT>6-sec	.93
P35	Yoke	0
P67	IRT>6-sec	.95
P69	Yoke	.99

The stimulus conditions that were varied in the experiment affected not only the rates of response but also the latency of response of the birds in the IRT>6-sec condition. Figure 2 shows the relative frequency of occurrence of various response latencies in Phases 1, 2, 4, and 6. The latency distributions from Phases 3, 5, and 7 were so similar to those of Phase 1 that they will not be presented here. As Figure 2 shows, there were only slight differences in the relative frequency distributions for the positive and the uncorrelated conditions. Thus, the elimination of the positive correlation between the light and food in Phase 2 had substantial effects on the rate of response (See Figure 1) but had only slight effects on the latency of response. In both the positive and the uncorrelated conditions, the modal latency was two to three seconds. More latencies greater than two seconds occurred in the uncorrelated condition than in the positive condition. However, in both the positive and the uncorrelated conditions, less than 5% of the latencies exceeded 6 sec. Thus, reinforced responses occurred in less than 5% of the trials.

Figure 2 shows that in the negative correlation condition, the relative frequency distributions were very similar to those from the uncorrelated condition. The major difference was a slight increase in the negative condition in the relative frequency of latencies greater than 6 sec. For each bird, more than 80% of the response latencies were too short to satisfy the requirements of the IRT>6-sec schedule.

The largest change in the latency distributions occurred in Phase 6 in which the S^D was no longer presented on the key. In Phase 6, there were large increases in the relative frequency of latencies longer than the modal latencies from the previous conditions. Fur-

thermore, the distributions were generally peaked at a value close to the minimal value of 6 sec required for reinforcement. For three of four birds, there was an increase in the relative frequency of response latencies that fell within the range required for reinforcement. That increase was quite large in two of the birds, and by the end of Phase 6 those birds emitted reinforced responses on half of the trials.

In this experiment, the stimulus-reinforcer correlation was manipulated through the procedure described above by varying the rate of food presentation between trials. The procedure used in the uncorrelated condition was designed in such a way that the overall rate of food presentation between trials in a particular session equaled or exceeded the overall rate of food presentation within the trials of that session. In fact, that procedure was effective, for in the uncorrelated condition, the intratrial rate of food presentation never exceeded and was often considerably less than the intertrial rate of food presentation (the data for all sessions are obtainable on request to the author). The largest differences between the intratrial and the intertrial rates of food delivery occurred in sessions in which only one or two reinforced responses occurred. On those occasions, the intratrial rate of reinforcement was very low (around .2 per min), whereas the minimum programmed rate of reinforcement between trials remained relatively high (1 per min).

In the negative correlation condition, food was programmed to be delivered at least twice as often between trials as within trials. In fact, that procedure was also effective, for the actual rate of food presentation between trials was always twice as large (and often three times larger) than the rate of food presentation within trials.

DISCUSSION

In the present experiment, when the light and food were positively correlated, the response rates of the birds in the IRT>6-sec condition were relatively high, and reinforcers were obtained on less than 5% of the trials. That result confirms the observations made by Schwartz and Williams (1971), for in that study, reinforced responses occurred on less than 10% of the trials in a positive correlation condition similar to the present one.
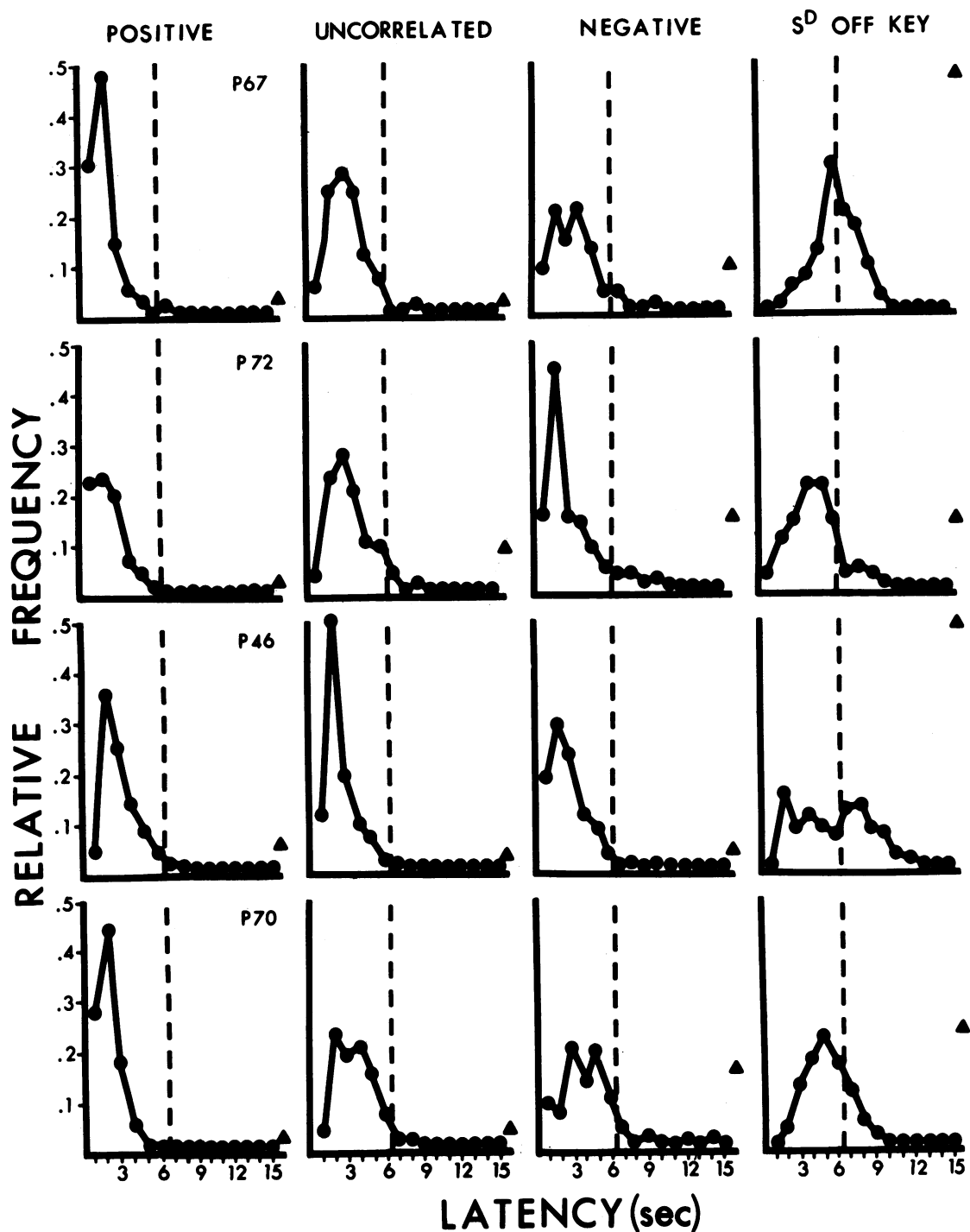
Fig. 2. The relative frequency of occurrence of latencies for each subject in the IRT>6-sec condition in various phases of the experiment. Each graph shows data averaged over the last five sessions of the particular condition. The solid triangles show the relative frequency of all latencies greater than the 6 sec required for reinforcement.

The stimulus-reinforcer correlation in this experiment clearly influenced the responding of the birds in the yoked condition and in the IRT>6-sec condition. For the birds in the yoked condition, pecking occurred at a high rate when the light was positively correlated with food, just as in previous studies of auto-shaping (Gamzu & Williams, 1971, 1973; Wasserman et al., 1974). Similarly, the rates of response of the birds in the IRT>6-sec condition were relatively high when there was a positive correlation between the light and the food. When the light and the food were uncorrelated (Phase 2), the pecking of the yoked birds was greatly reduced in frequency or was completely eliminated. Likewise, the elimination of the positive correlation between the light and food resulted in substantial reductions in the response rates of the birds in the IRT>6-sec condition. When the light and the food were negatively correlated (Phase 4), the pecking of the birds in the yoked condition rapidly declined to a level at or near zero. The negative correlation between the light and the food also brought about large decrements in the responding of the birds in the IRT>6-sec condition. Although the zero and the negative correlation between the light and the food reduced the pecking of the birds in both the yoked and the IRT>6-sec conditions, the magnitude of the reduction was much larger in the yoked condition, and the reasons for this difference shall be discussed shortly.

Further evidence of the influence of the stimulus-reinforcer correlation comes from the condition in which the keylight was no longer the S^D. For two of three birds in the yoked condition, pecking ceased when the light remained on constantly and the offset of the white noise was positively correlated with the delivery of food (Phase 6). The pecking that was maintained for the one bird during Phase 6 appeared to be controlled by reinforcement. The continuation of pecking for that bird was probably due to the frequent but chance occurrence of pecks in the late portions of trials in which food was presented. If pecks in the presence but not the absence of the S^D were followed by the reinforcer, then pecking should come to be controlled by the S^D, and that is exactly what happened. For the birds in the IRT>6-sec condition, the response rates in Phase 6 declined to a level as low as (one

bird) or lower than (three birds) that which had occurred in any previous condition.

Several aspects of the results for the birds in the IRT>6-sec condition merit further discussion. In the condition in which the S^D was not on the key, the percentage of trials in which a reinforcer was obtained was high relative to the other conditions of the experiment, yet reinforced responses occurred at most on only about 50% of the trials. In the experiment by Schwartz and Williams (1971), reinforced responses were observed to occur in about 75% of the trials provided that collateral pecking responses on another key occurred. Thus, even when the light in this experiment no longer signaled the delivery of food, the performance on the IRT>6-sec schedule did not reach the level that might have been reached if pecking had been established as an effective mediating response. Since performance in Phase 6 of this experiment did not reach the level at which a very high percentage of the available reinforcers were obtained, the low percentage of trials in which a reinforced response occurred in Phases 1, 3, 5, and 7 may not be attributed entirely to the positive correlation between the light and food. That conclusion is consistent with the results of previous studies (e.g., Laties et al., 1969; McMillan, 1969; Schwartz & Williams, 1971; Zuriff, 1969) that have shown that in a wide variety of procedures, the occurrence of mediating responses substantially improves the rate of reinforcement in IRT>6-sec schedules.

A perplexing but important aspect of the results obtained from the birds in the IRT>6-sec condition is that when the light and food were either uncorrelated or negatively correlated, the response rate remained relatively high and few reinforcers were obtained. Those results are surprising since without a positive light-food correlation, pecking should presumably have been controlled by the IRT>6-sec dependency as it was when the S^D was not on the key. Indeed, in the negative correlation condition, the stimulus-reinforcer and the response-reinforcer relationships should have acted in concert to decrease the response rate and to increase the percentage of trials in which a reinforced response occurred. The lack of decrease in response rate under the IRT>6-sec schedule may not reasonably be attributed to subtle procedural variables such as the lighting conditions, the duration of the trials, and

so on, for the pecking of the birds in the yoked condition was strongly controlled by the identical stimulus-reinforcer correlations that occurred in the IRT>6-sec procedure. Thus, the solution to the problem must be sought in the IRT>6-sec procedure itself.

There are at least three conceivable accounts of why response rate under the IRT>6-sec schedule did not decrease substantially when the light and food were either uncorrelated or negatively correlated. One possible account is that in the latter conditions, nonreinforced intratrial pecks were maintained by adventitious reinforcement. Since food was sometimes delivered in the intertrial interval 6 sec after the end of the trial, nonreinforced responses that occurred at the end of the trial were intermittently followed by food presentations after a delay of 6 sec. However, that account seems implausible for numerous reasons. First, 6 sec is too long a delay between the response and the reinforcer to have very large effects on responses (Catania, 1971). Also, food was not always delivered 6 sec after each trial, for food was presented in the intertrial interval on a probabilistic basis, and in the uncorrelated condition the probability with which food was presented was rather low. Another problem with that account is that the intratrial pecks of the birds in the yoked condition occurred often in the early sessions of the uncorrelated condition. Although those nonreinforced responses were, like the nonreinforced responses of the birds in the IRT>6-sec condition, sometimes followed by food after a delay of 6 sec, the pecking of the yoked birds was not maintained.

A second account of the performance on the IRT>6-sec schedule in the uncorrelated and the negative correlation appeals to the activation-inducing properties of food presentation. If the increases in the frequency of food presentation within sessions had increased the level of general activation, then the effects of increased activation were confounded with the manipulations of the light-food correlation. Since food was presented more frequently in, say, the uncorrelated condition than in the positive correlation condition, the level of activation was presumably higher in the uncorrelated condition. The increased level of activation, in turn, could have led to an increased rate of pecking on the IRT>6-sec schedule. That account encounters numerous difficulties. The first one is that the frequency of food presentation and, thus, the level of activation would have been much higher in the negative correlation condition than in the uncorrelated condition, and pecking should therefore have occurred at a higher rate in the negative condition. Contrary to that prediction, the rate of pecking was lower in the negative correlation than in the uncorrelated condition. Of course, one could argue that the effects of the increased activation level were offset by the establishment of a negative correlation between the light and food, but the account would remain weak. The account in terms of activation level does not explain why the level of activation differentially influenced the rates of the birds in the IRT>6-sec condition.

The third and most plausible account of the performance on the IRT>6-sec schedule in the uncorrelated and the negative correlation conditions is that the increased rates of food presentation between trials did not completely eliminate the eliciting effects of the light. That account is consistent with the observation that removing the S^D from the key led to very large decreases in the response rates and to substantial increases in the percentage of trials in which reinforced responses occurred. On a procedural level, the light was not positively correlated with the presentation of food in either the uncorrelated condition, the negative correlation condition, or the condition in which the S^D was not on the key. Nevertheless, the light may have continued to elicit pecking in the former two conditions.

The preceding conclusion has important methodological implications. In many studies of the role of the stimulus-reinforcer correlation in operant conditioning procedures, the stimulus-reinforcer correlation is varied by changing the intertrial rate of food presentation. But, as pointed out above, the elimination of the positive stimulus-reinforcer correlation does not necessarily eliminate the eliciting effects of the stimulus. In the future, it may be wise simply to vary the stimulus-reinforcer correlation and also to systematically compare performance in two situations: those in which the S^D is localized and on the manipulandum and those in which the S^D is not on the manipulandum (e.g., LoLordo, McMillan, & Riley, 1974; Hearst & Jenkins, 1974; Keller, 1974; Schwartz, 1975, 1976).

Assuming that the eliciting effects of the light were incompletely eliminated in the uncorrelated and the negative correlation conditions, an important question arises. Why were the eliciting effects of the light eliminated successfully in the yoked condition but not in the IRT>6-sec condition? Recall that the light-food correlation was identical in both conditions. One plausible answer is that in the uncorrelated and the negative correlation conditions, the behavior of the yoked birds but not of the birds on the IRT>6-sec schedule came to be controlled by background stimuli (cf. Tomie, 1976a, 1976b). In the yoked condition, food was always delivered independently of responding. When food was presented often in the intertrial interval, background stimuli from, say, the front wall of the chamber were present at the time of food delivery, and the keylight was not differentially paired with food. Accordingly, the control of behavior by the keylight decreased and the control exerted by the background stimuli increased (this account is fully consistent with a relational view of reinforcement: cf. Donahoe, 1977; Rescorla, 1975). In contrast, the background stimuli would presumably not acquire full control over behavior in the IRT>6-sec condition since in that condition, reinforcement was dependent on pecking in the presence of the light. Thus, as the result of reinforcement in the IRT>6-sec condition, the keylight competed with the background stimuli for the control of behavior. The behavior of the birds in the IRT>6-sec condition may have been controlled within trials by concurrent stimuli: Nonpecking responses were presumably controlled by the background stimuli, and both pecking and nonpecking responses were controlled by the keylight. The end result was that the behavior that occurred within trials could have been a mixture of nonpecking responses controlled by the background stimuli and the pecking and the nonpecking responses that were controlled by the keylight.

The preceding account is fully consistent with the casual observations of behavior that were made throughout the experiment. During the sessions of the uncorrelated and the negative correlation conditions, the birds in both the yoked and the IRT>6-sec conditions often emitted stereotyped pacing and orientation responses during the intertrial intervals. For the birds in the yoked condition, those same behaviors occurred in the presence of the keylight, and, of course, were occasionally followed by the presentation of food. For the birds in the IRT>6-sec condition, however, the pacing and orientation responses that occurred in the intertrial intervals were intermixed during trials with pecks at the key. Thus, the relatively high rate of response and low rate of reinforcement on the IRT>6-sec schedule in the uncorrelated and the negatively correlated conditions may be accounted for in terms of the failure of background stimuli to acquire full control over behavior. Of course, the preceding account is speculative at this point, and attempts are now being made in this lab to record automatically those responses that may be controlled by the hypothesized background stimuli.

In the preceding account, the effects of the stimulus-reinforcer correlation in operant conditioning procedures do not depend entirely on factors such as the location of the S^D, the degree of localization of the S^D, the nature of the response, the direction of the effects of the response-reinforcer variables relative to the effects of the stimulus-reinforcer variables, and so on. The effects of the stimulus-reinforcer correlation may also depend on whether and to what extent variation in the stimulus-reinforcer correlation establishes control of responses by background stimuli that compete with the control of responding by the S^D. This point may be clarified by considering a discrete trials omission procedure in which a key is intermittently illuminated and reinforcers are presented within trials following t sec in which no pecks have occurred. When food is not presented between trials, pecking continues to occur in a substantial percentage of trials despite the consequent nonreinforcement (William & Williams, 1969). Now consider what might happen if food were presented between trials independently of responding and at the same rate as within trials. In that case, background stimuli would acquire control over the nonpecking responses that precede food presentation in the intertrial interval. Since the background stimuli are present during trials, the nonpecking responses occasioned by those stimuli might also occur during trials. Due to the nature of the schedule of reinforcement, those nonpecking responses would be reinforced. Since nonpecking responses would be reinforced equally often in

the presence and the absence of the light, the light would cease to control responding and would no longer elicit pecking. Consequently, the rate of intratrial pecking should decrease to a level near zero, just as occurred for the birds in the yoked condition but not in the IRT>6-sec condition of the present experiment.

Whether the results of the preceding hypothetical example would be as predicted above remains to be determined by future research. The important point for now is that removing a positive stimulus-reinforcer correlation may have very different effects in different operant conditioning procedures. Furthermore, eliminating a positive stimulus-reinforcer correlation may have different effects in the same operant conditioning procedure. In the present experiment, the elimination of the light-food correlation did not reduce responding in the IRT>6-sec condition. The opposite results might have been obtained if the food in the intertrial interval had been presented according to, say, a variable-interval schedule at a rate equal to the intratrial rate of reinforcement. It might be objected that the latter procedure confounds changes in stimulus-reinforcer variables with changes in response-reinforcer variables. Yet that is just the point, for changes in the stimulus-reinforcer correlation typically lead to changes in the reinforcement of responses in the presence of background stimuli. To fully understand the effects of stimulus-reinforcer correlations, it is necessary to study the effects of many different combinations of stimuli, responses, and reinforcers not only within trials (e.g., Jenkins, 1977) but also between trials.

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